

# External costs: definition and their quantification

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## Externality as a source of market failure

- deviation from the first-best neoclassical world in which the price mechanism takes care of socially optimal /efficient resource allocation (Pareto efficiency)
- *signal failure* → market prices no longer reflect social costs (or benefits) and additional taxes (or subsidies) are called for to restore the efficient workings of the market mechanism (Himanen, Nijkamp, and Padjen, 1993)
- the source of externalities is typically to be found in the "absence of property rights" (Baumol & Oates, 1988)
  - environmental quality is a typical "good" for which property rights are not defined and equivalently no market exists



## Externality definition

- "...externality arises when the social or economic activities of one group of persons have an impact on another group and when that impacts is not fully accounted, or compensated for; by the first group" (EC 2003)
- well-known textbook example-> upstream industry discharges waste to a river → loss of dissolved oxygen
  - loss of fish stock in the river
  - financial (and recreational) losses to anglers downstream
    - if not compensated for their loss of welfare, the upstream industry will continue its activities as if the damage done downstream was irrelevant to them
- ...they are said to create an external effect
- An external costs exists when two conditions prevail>
  1. An activity by **one** agent **causes a loss of welfare** to **another** agent
  2. The loss of welfare **is uncompensated**



(Pearce et Turner 1991)

## Externality definition

- The externalities used to be named as external effects, external positive or negative savings, or sometimes technological external effects
- ...are related with mutual **interactions of utility and production functions**
- „An external effect exists when an actor's (the receptor's) utility (or profit) function contains **a real variable** whose actual value depends on the behaviour of another actor (the supplier), who **does not take** these effects of his behaviour **into account** in his decision making process" (Mishan, 1971; Baumol and Oates, 1988; Verhoef 1994; 2002)
- The essential feature of an external effect [is] that the effect produced is **not a deliberate creation** but an **intended** or **incidental by-product** of some otherwise legitimate activity (Mishan, 1971; cit in: Verhoef 2002)



## Externality definition

- In line with standard terminology of
  - Viner (1931) or Scitovski (1954) that concerns „**technological**“ **externalities** (as opposed to „pecuniary externalities“)
  - Buchanan and Stubblebine (1962) --- externalities are potentially „**Pareto relevant**“
    - if the costs of correcting for the market failure do not exceed the welfare gains to be obtained)



## the effects that do not qualify as the externalities

### External relations

- the effect should not be taken into account in supplier's decision-making process...
- individual welfare maximizing behaviour is perfectly in line with Pareto optimality
  - *barter trade* → involves no external benefit
  - *criminal (violent) activities* → the supplier's U(x) may include the receptor's utility level as determining variable
  - *altruism and charity*
- policy action only if based on socially considerations

### Pecuniary externalities

- true (technological) externalities aim at **real variables**, i.e. excluding monetary ones
- ordinary economic dependencies acting through market
- do not lead to shifts in production or utility functions but merely to movements **along these functions**
  - no interventions is required to secure Pareto efficiency



## Externality definition > summary

- change in welfare (due to mutual interactions of  $U(x)$  or  $Q(x)$  functions)
- caused by one agent to another one
- is not compensated
- is not mediated by market (and money), but is rather direct (it is not pecuniary effect)
- is not a deliberate creation but an intended or incidental by-product (not external relation)
- requires state an intervention to restore the efficient workings of the market mechanism
  - if voluntary action was not feasible (see the Coase theorem (1960) and its assumptions, i.e. low transaction costs, property rights well/defined and enforced)

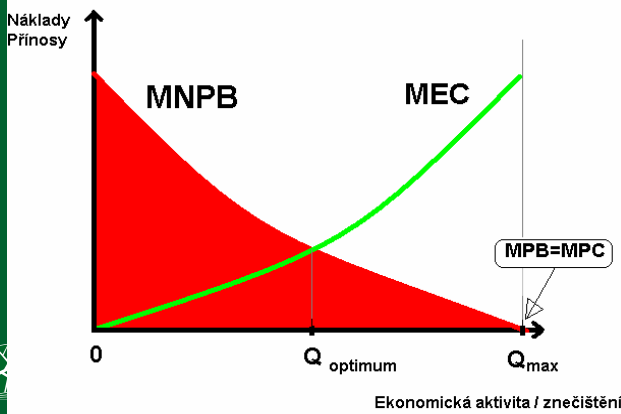


## Externality classification

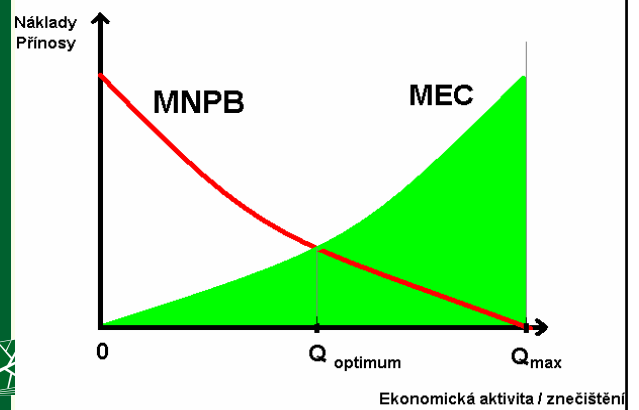
- **positive** versus **negative**
- **production** versus **consumption** - related
- **neighbourhood effects** (or effects of overflowing)
  - an alternative name of externality with spatial dimension, e.g. impacts caused by steel factory to persons living in way of wind direction (Pearce et al. 1992)
- **depletable** versus **undepletable**
  - consumption of undepletable externality by one of its recipient does not influence its consumption by another one. Undepletable externalities also qualify as public goods
- **congestion externality**
  - agent is simultaneously supplier as well as recipient of the externality, e.g. congestion in road transport
- **partial** versus **global**
  - classified according to its potential spatial impacts
- **intergeneration**
  - related with intergenerational equity, e.g. a depletion of non-renewable resource (Stiglitz)
- **x-dimensional**
  - catching fish: fisherman  $\leftrightarrow$  boating: fisherman  $\leftrightarrow$  boating  $\leftrightarrow$  swimming...
- **marginal** versus **inframarginal**



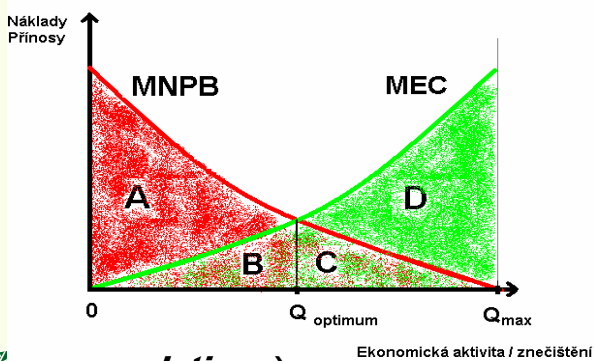
## Optimal level of regulation



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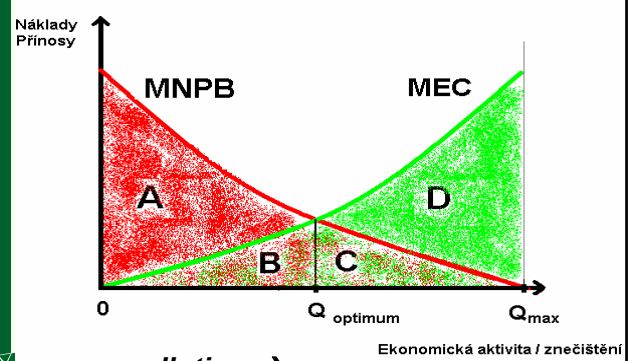
## Optimal level of regulation



...no regulation  $\rightarrow Q=Q_{max}$

$$\text{Social Welfare} = (A+B+C) - (B+C+D) = A - D$$

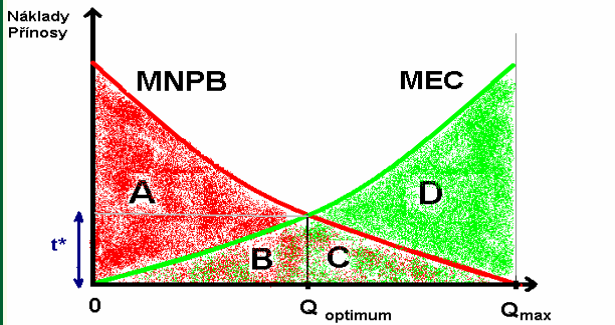
## Optimal level of externality



...zero pollution  $\rightarrow Q=0$

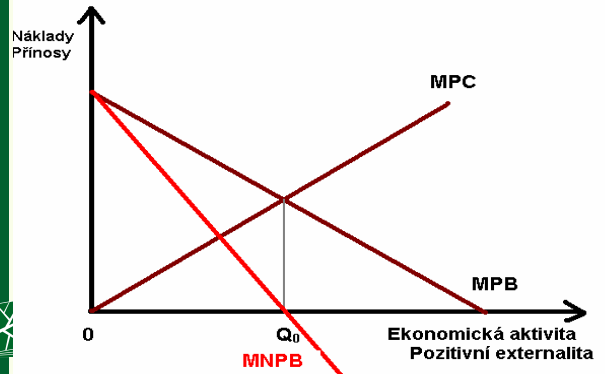
$$\text{Social Welfare} = (0) - (0) = 0$$

### Optimal level of externality

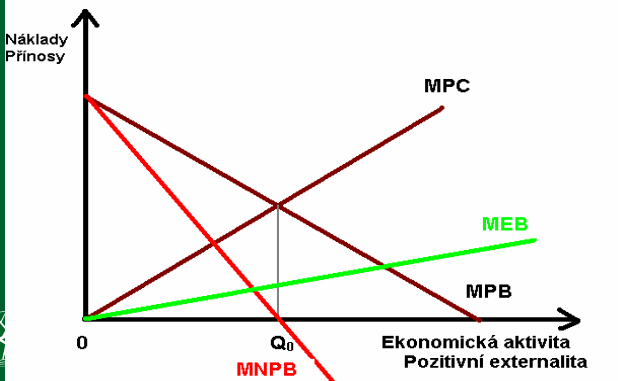


**..optimum** →  $Q=Q^*$   
**Social Welfare = (A + B) - (B) = A**

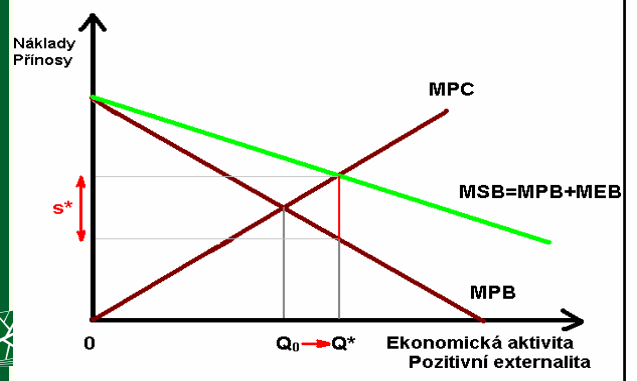
### Optimal level of regulation (positive externalities)



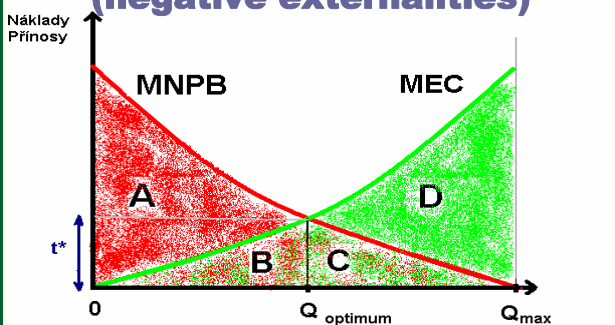
### Optimal level of regulation (positive externalities)



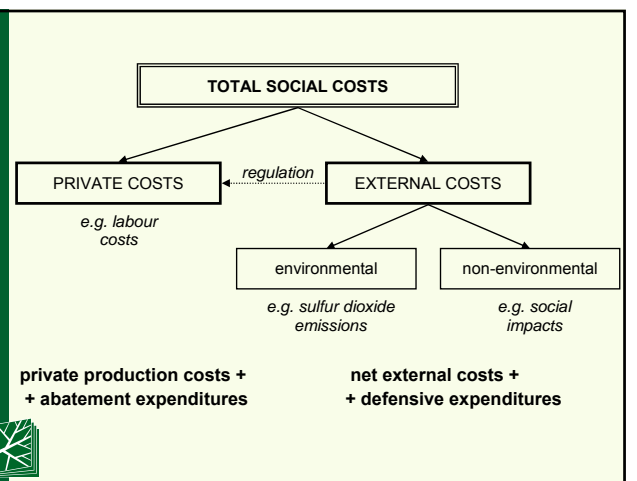
### Optimal level of regulation (positive externalities)



### Optimal level of externality (negative externalities)



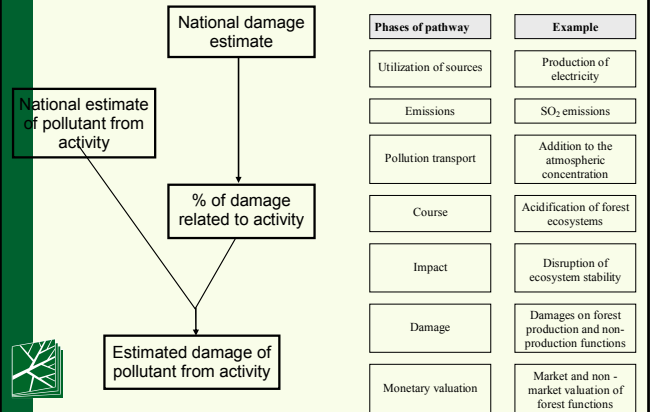
**..optimum**  
 $Q=Q^*$ : **total social welfare = (A + B) - (B) = A**



## II EXTERNALITY QUANTIFICATION



### Top-down vs. Bottom-up



### Monetary valuation

#### Short-cut approaches

- costs of actual or potential defensive or abatement program
- net external cost is neglected

#### Valuation approaches

- Physical interlinkages between the cause and the damage
  - Non-behavioural linkage
  - damage function, dose-response function (or ERFs, CRFs)
- Behavioural linkage
  - based on revealed preferences (travel costs, averting behaviour, hedonic price/wage model)
  - based on stated preference (contingent valuation, choice experiment)



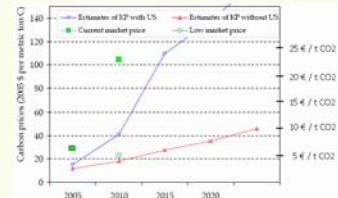
### Damages due to Climate Change

#### Shadow price - marginal abatement costs

- involved costs to reach certain policy goal →
  - to keep Kyoto target → 19€ t CO<sub>2</sub> (ExternE reference value)
  - NEEDS by R.Tol → 38€ → 74€ → 182€ → 349€ tCO<sub>2</sub> (2050)  
750ppm/3.2°C → 650ppm → 550ppm → 500ppm/2.2°C
- market price of allowances (e.g. in EU/ETS)
  - EU ETS Allowance: 7.05€ t CO<sub>2</sub> (6 Dec 2006; www.PointCarbon.org)

#### Carbon Price in Europe

Source: Nordhaus 2005; estimates by RICE-2001 & PointCarbon.com (changes by presenters)



### Marginal Social Costs of Carbon

\$/tCO2 (\$1995)	Mode	Mean	5%	10%	Median	90%	95%
Base	0,4	25,4	-2,7	-0,5	3,8	45,0	95,5
Author-weights	0,4	35	-3	-0,5	4	60	173
<b>Peer-reviewed only</b>	1,4	<b>14</b>	-2	-0,5	<b>4</b>	34	67
No equity weights	0,4	25	-2	-0,5	3	32	82
Equity weights	-0,1	28	-5	-0,5	15	68	108
P RTP=3% only	0,4	4	-2	-0,5	2	10	17
P RTP=1% only	1,3	14	-4	-0,5	9	34	45
P RTP≤ 0% only	1,9	71	-7	-0,5	11	206	439

Tol (2004)



### Damages due to Climate Change

#### Marginal Social Costs == Externalities

- Integrated Assessment Models
  - RICE-2001 (Nordhaus 2005)
    - 16\$ per t carbon (4.4€ per t CO<sub>2</sub>) in 2010 (in 2005 prices) balance the costs and benefits
    - price of carbon is rising rapidly over time
  - Stern Review (2006) → 85\$ t CO<sub>2</sub> (if no action)
  - FUND models (ExternE; Richard Tol)
    - MethodEx> MSC of CO<sub>2</sub> up to 50\$
    - NEEDS> MSC of t C between 0.5\$ to 17\$ and declining over time
- a mixture of positive and normative approaches needed!



## Time profile of damages

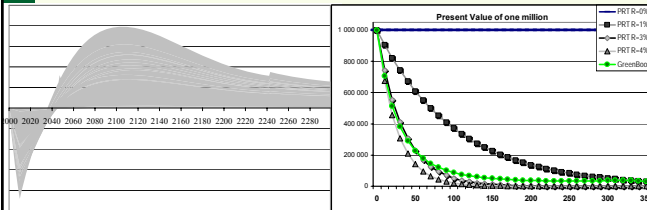
- Early benefits due to agricultural gains in productivity
  - benefits affect discounted values of later damages
  - point of cross-over is critical in discounted values

### FUND time profile

source: Downing (MethodEx 2005)

### Present Value of One Million €

300,000€ in 30y vs. 121€ in 230y (3.5%)



## Welfare assessment along time in FUND model

- Assuming a logarithmic utility function, the consumption discount rate equals the growth rate of per capita income plus the pure rate of time preference (PRTR)
  - **Ramsey discounting** (neo-classical, conventional, geometric, or exponential) with
    - 3 PRTR equals to 0%, 1%, 3%
  - **Hyperbolic discounting (gamma, Weitzman)**
    - GreenBook (declining rate from 3.5% to 1% in year 300)
    - Weitzman (initial PRTR of 3% falling to 1% after 25 years)



## Distributional concerns How to value damage outside of EU25?

1. **compensation** a judge or jury would award, **correcting for the probability that an outsider would indeed win the court**
2. **fair compensation** („a perfect judge/jury“) that offsets the damage done (the probability of being held liable is unity) → **regional values**
3. **observed altruism of EU residents to outsiders** (assumes a global social planner), e.g. as same as for the EU residents or weighted by
  - explicit distributional weights → **equity-weighted values**
    - based on a judgment about the importance of income to those who gain or lose (Pearce-Atkinson-Mourato 2006)
    - if diminishing marginal utility of income holds, the utility of a unit change in a poor individual's income is greater than the utility value of the same unit change of rich person → *dollar received by richer gets less weight than dollar for the poor*
    - possible weight is >  $w_i = (Y/Y_i)^e$ , where  $e$  is the elasticity of MU of income, and  $Y$  is average income



## General conclusions

- MSC of C is higher if
  - equity-weighted
  - discounted by higher rate
  - discounted exponentially rather than hyperbolically
  - means rather than medians used (mean > 1%trimmean > 5%trimmean > median)
- MSC of C values
  - differ for various GHG emissions (GWP changes...)
  - vary over time
    - adaptive measures
    - non-linearities



## III Externality quantification (on the ExterneE method)



## ExterneE project series

*Project ExterneE = Externalities of Energy* launched in 1991, financed by DG Research within the Joule programme

### Scope

- airborne pollutants from power plants
- development of the Impact Pathway Approach

### Follow-up projects

- improving and extending the methodology
- extending the field of applications: heat production, transport, industrial activities, agriculture



## ExternE: Basic principles

1. Assessment of effects/damage (e.g. health risk), not of pressures (e.g. emissions of pollutants)

2. Relation between pressure and effect is in general non-linear

3. Effects depend:

- > site of activity
- > technology
- > time



Bottom-up approach needed for the complex pathways: the 'impact pathway approach'

- > preference structure of the population



Valuation methods are used  
e.g. contingent valuation method



## Impact pathway approach

POLLUTANT & NOISE EMISSIONS

TRANSPORT & CHEMICAL TRANSFORMATION

DIFFERENCES OF PHYSICAL IMPACTS

MONETARY VALUATION



## Impact Pathway Approach

- Assessment of impacts is needed at **each spatial levels**: local, regional, hemispheric, global. The relative importance of larger scale impacts is increasing.
- **Life cycle impacts** (construction and dismantling, provision of fuels, waste treatment and disposal) should be taken into account (especially important for electricity production from renewable and nuclear energy).



Impacts included in the current ExternE projects

Pollutant/burden

Impact category

- Particulate matters
- SO<sub>2</sub>, NO<sub>x</sub>
- CO<sub>2</sub>
- O<sub>3</sub>
- Heavy metals
- CO, VOC
- Noise
- Odour

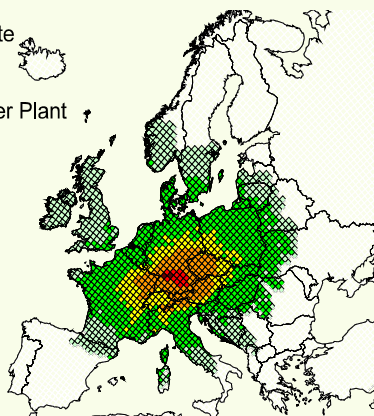
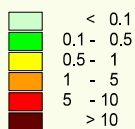


- Human health
  - morbidity
  - mortality
- Building materials
- Crops
- Climate change
- Forests
- Natural ecosystems
- Visibility
- Cultural heritage



Additional Sulfate Concentration caused by Coal Fired Power Plant in Lauffen

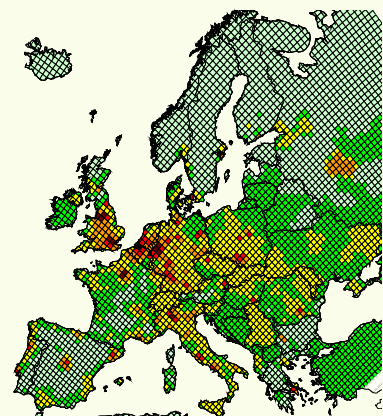
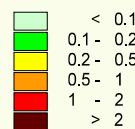
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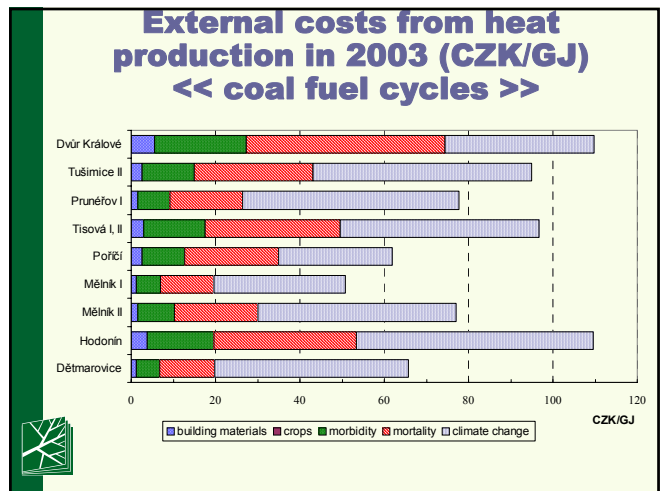
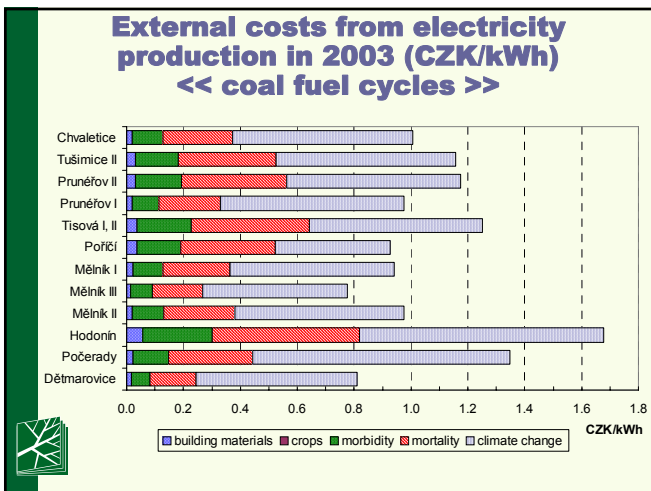
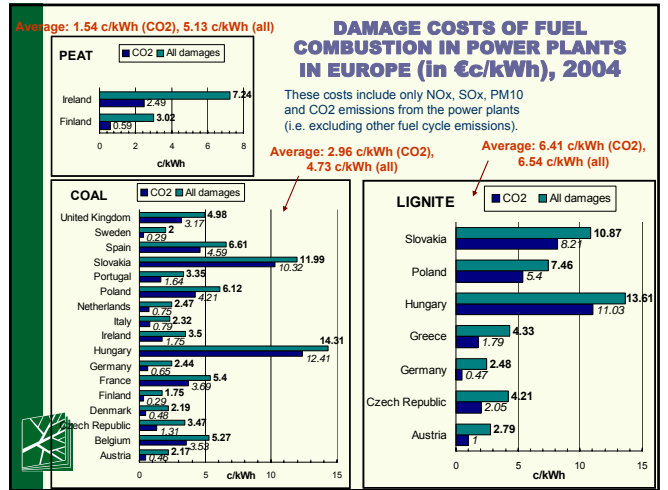
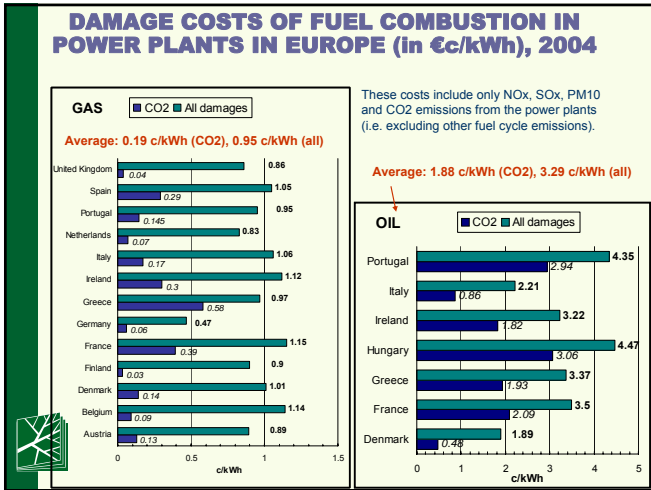
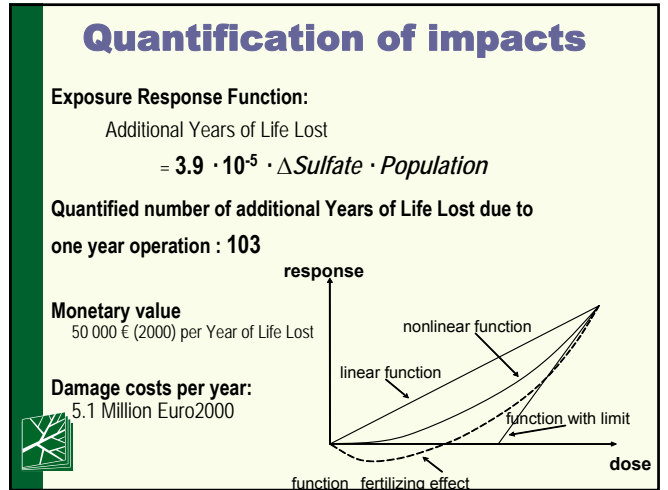
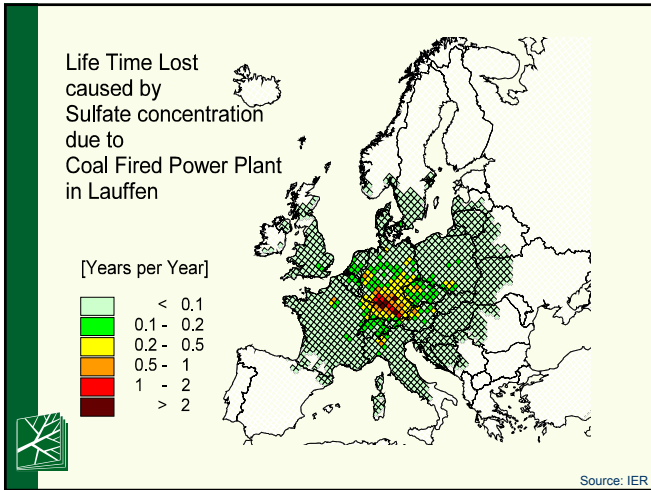
Population in Europe

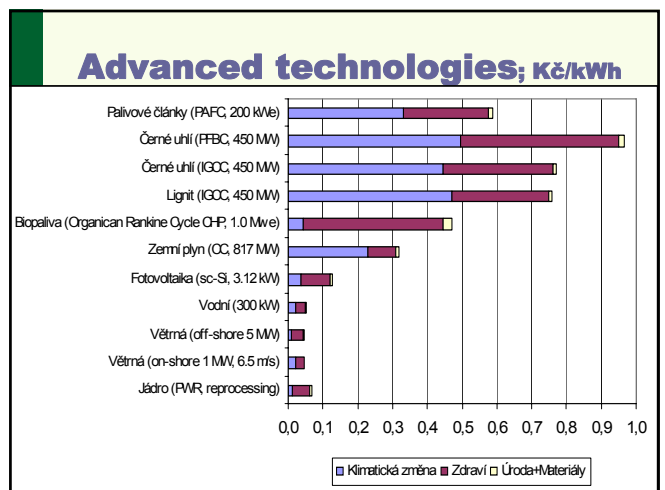
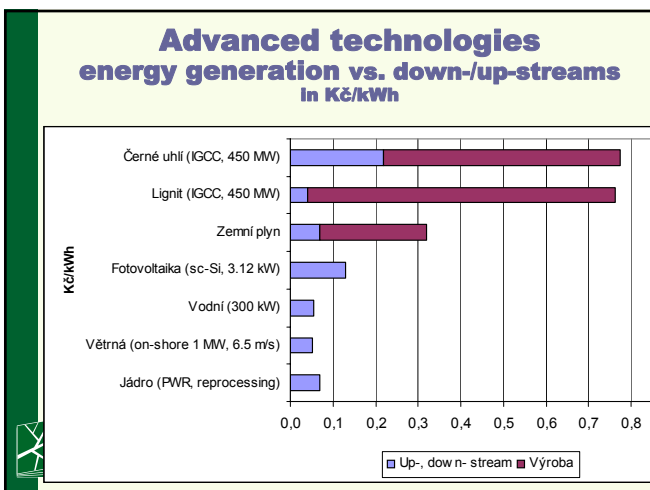
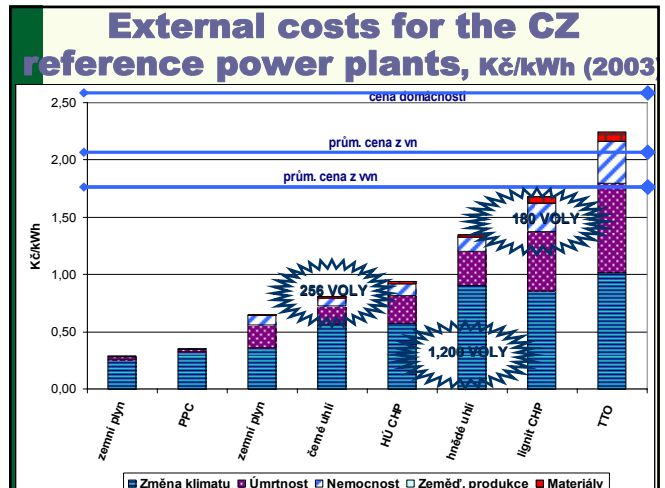
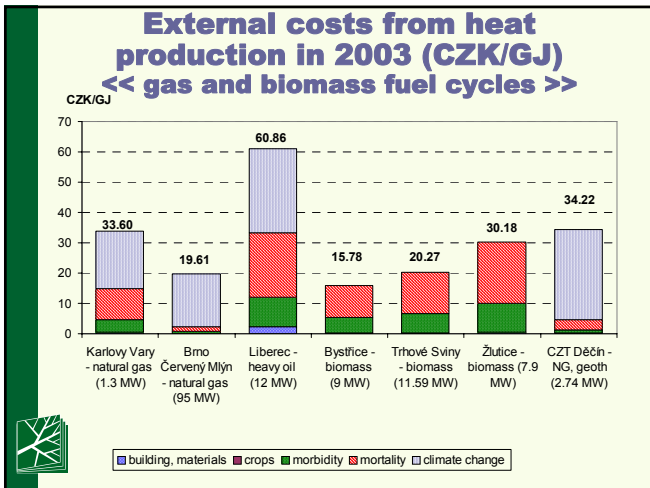
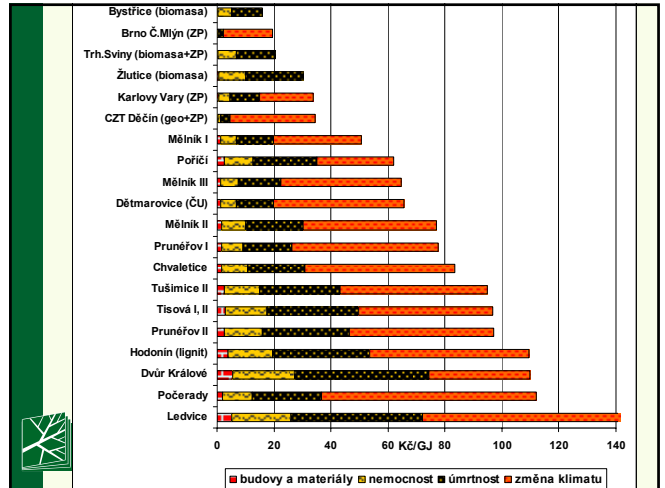
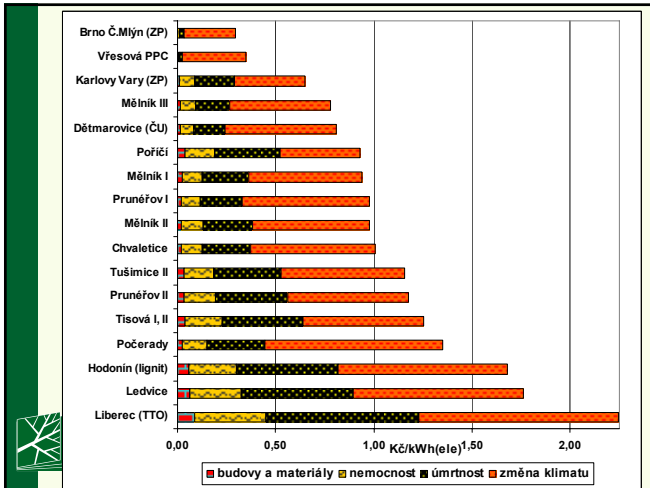
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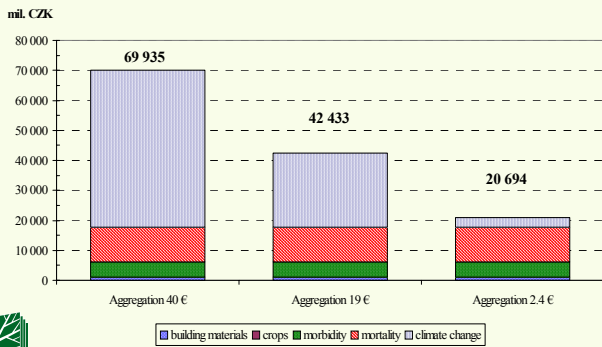




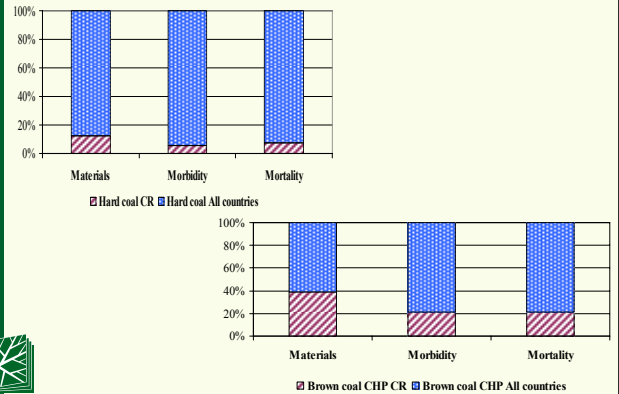




## Aggregation of the external costs << 4 Czech coal power plant >>

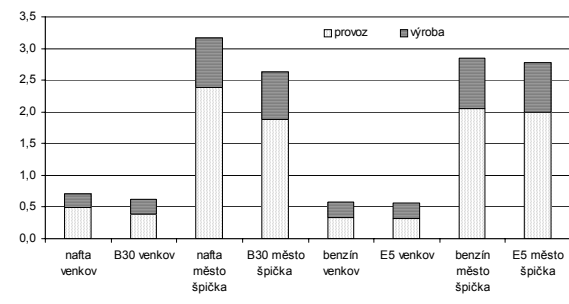


## SPATIAL ALLOCATION OF EXTERNALITIES PM, SO<sub>2</sub>, NO<sub>x</sub>: Czech Republic vs. rest of the world

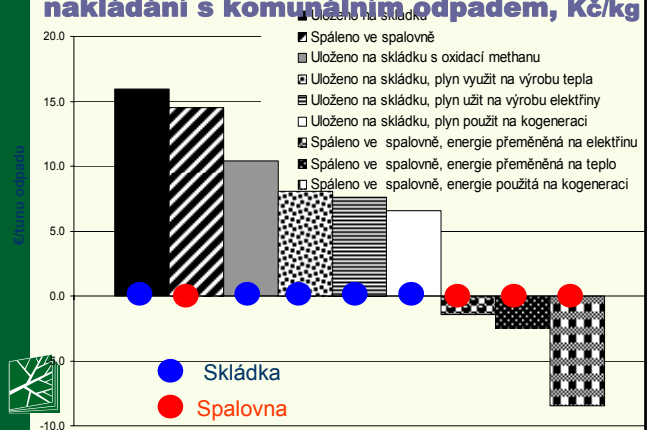


## Externí náklady výroba + provoz

v EUR/100 vozokm (osobní auto/EURO III/1,4-2,0 l)



## Volba politiky / kriterií: nakládání s komunálním odpadem, Kč/kg



## The ExternE reference point

ExternE website ⇒ [www.externe.info](http://www.externe.info)

- ExternE methodology 95
- National Implementation
- Final reports of ExternE projects
- Information brochure on external costs (2003)
- Methodology 2005-update



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